B.10 POROUS PAVEMENT

DESCRIPTION

Porous pavement is an asphalt based paving material that allows stormwater to quickly infiltrate the surface pavement layer to enter into a high-void aggregate sub-base layer. The captured runoff is stored in this "reservoir" layer until it either infiltrates into the underlying soil strata or is routed through an underdrain system to a conventional stormwater conveyance system. Porous pavements operate in a similar fashion to infiltration trenches and thus provide similar water quality benefits. An example of a typical porous pavement system is shown in Figure 1.

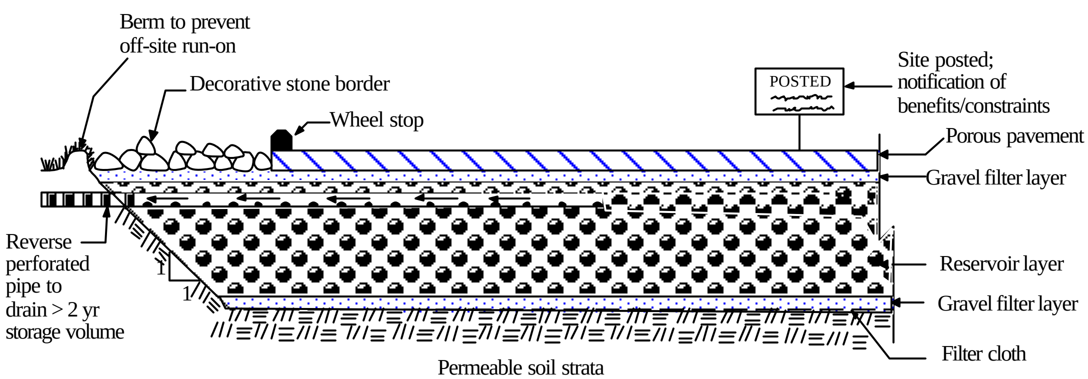

Figure 1. Schematic of porous pavement system.

ADVANTAGES

1, Porous pavements operate in a similar fashion to infiltration trenches and thus provide similar water quality benefits, including reductions in fine grained sediments, nutrients, organic matter, and trace metals.
2. In addition to water quality benefits, porous pavements also provide significant reductions in surface runoff with up to 90 percent of rainfall retained within the BMP (Schueler, 1992).
3. An added benefit provided by the on-site infiltration is the extent to which the stormwater runoff is able to contribute to groundwater recharge.
4. Reduces pavement ponding.

LIMITATIONS

1. Only applicable for low-traffic volume areas.
2. To maintain effectiveness, porous pavements require frequent maintenance.
3. Porous pavements are not intended to remove sediments.
4. Easily clogged by sediments if not situated properly.
5. Porous pavements are limited to treating small areas (0.25 to 10 acres).
6. Contributing drainage area slopes should be 5 percent or less to limit the amount of sediments that could potentially lead to clogging of the porous pavement.
7. On average, porous pavements clog within 5 years.
8. Underlying soil strata must have an adequate infiltration capacity of at least 0.3 inches per hour but preferably 0.50 in/hr or more. Adequate soil permeability should extend for a depth of at least 4 feet.
9. The bottom of the reservoir layer should be at least 4 feet above the seasonally high water table. Porous pavements should be no closer than 100 feet from drinking wells and 100 feet upgradient and 10 feet downgradient from building foundations. Due to the risk of groundwater contamination, porous pavements should not be used for gas stations or other areas with a relatively high potential for chemical spills. Similarly, special consideration should be given to the use of porous pavements in wellhead protection areas serviced by sole source aquifers.
10. The porous pavement should not be located where run-on from adjacent areas can introduce sediments to the pavement surface. Similarly, areas subject to wind-blown sediment loads should be avoided.
11. Extended rain can reduce the pavement's load bearing capacity.
12. More expensive than traditional paving surfaces.

DESIGN CRITERIA

A water quality porous pavement system provides only enough storage volume to capture the "first flush" of the rainfall. The "first flush" is defined as the runoff volume generated from 0.75-inches of rainfall. Calculate the volume of stormwater to be mitigated by the porous pavement using the Los Angeles County Department of Public Works *Method for Calculating Standard Urban Stormwater Mitigation Plan (SUSMP) Flow Rates and Volumes Based on 0.75-inches of Rainfall*. The remaining storm volume bypasses the BMP and is routed to a conventional stormwater conveyance system.

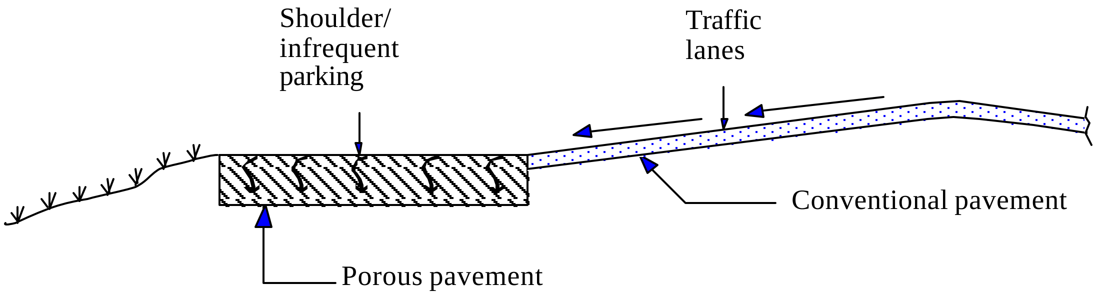

Figure 2. Schematic of a combination conventional/porous pavement system.

1. The prediction of the rate of infiltration of water through natural soils is related to soil type, porosity, degree of compaction, moisture content, and field capacity. This complexity governs soil drain times and has made the development of a single comprehensive model to predict drain times in actual porous pavement applications difficult. However, determining drain time is the key element in designing the size of porous pavement systems. The depth of the sub-base can be determined by:

$$H_d = \frac{E \times t_d}{r}$$

Where:

H_d	=	Depth of reservoir layer (in).
t_d	=	Detention time (hr).
E	=	Soil infiltration rate (in/hr).
r	=	Void ratio.

The required porous pavement surface area can then be computed by:

$$A_s = \frac{V}{r \times H_d}$$

Where:

A_s	=	Porous pavement surface area (ft^2).
V	=	Water quality volume (ft^3).

Table 1 provides the required amount of porous pavement surface area per acre and the depth of the reservoir layer with the assumption that the area is completely impervious. Also assumed is that the void ratio is 0.4, typical value, and the detention time is 48 hours.

Table 1. Using a void ratio (r) of 0.4 and a detention time (t_d) of 48 hours the following porous pavement surface area and depth of reservoir layer that is required for the respective infiltration rates.

Soil infiltration rate **E (in/hr)**	**Depth of reservoir layer** **H_d (feet)**	**Porous pavement surface area per acre** **A_s ($feet^2$)**
0.27	2.7	2,521
0.30	3.0	2,269
0.35	3.5	1,945
0.40	4.0	1,702
0.45	4.5	1,513
0.50	5.0	1,361
0.55	5.5	1,238
0.60	6.0	1,134
0.65	6.5	1,047
0.70	7.0	972
0.75	7.5	908
0.80	8.0	851
0.85	8.5	801
0.90	9.0	756
0.95	9.5	716
1.00	10.0	681

2. *Specifications.* The cross-section typically consists of four layers, as shown in Figure 3. Descriptions of each of the layers is presented below.
3. *Asphalt Layer* - The surface asphalt layer consists of an open-graded asphalt

mixture ranging from depths of 2 to 4 inches depending on required bearing strength and pavement design requirements. Porous pavements contain approximately 16 percent voids, compared to 3 to 5 percent for conventional pavements, allowing runoff to quickly infiltrate. A recommended gradation specification for an open-graded aggregate mixture is presented in Table 2.

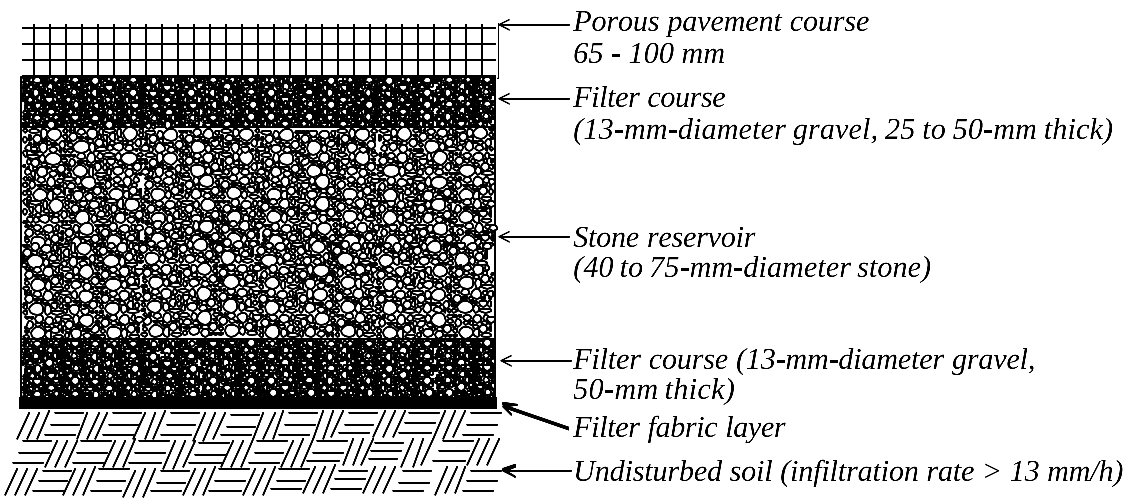

Figure 3. Schematic of typical porous pavement section.

Table 2. Aggregate gradation for porous pavement.

U.S. Sieve Series Size	***Opening (mm)***	***Percent Passing by Weight***
½ in	12.70	100
3/8 in	9.51	95-100
#4	4.76	30-50
#8	2.38	5-15
#200[1]	0.074	2-5

Note : 1. Aggregate should be uniformly graded between #8 and #200 sieve.

4. *Top Filter Layer.* Consists of a 0.5 inch diameter crushed stone to a depth of 1 to 2 inches. This layer serves to stabilize the porous asphalt layer. Table 2 provides typical details on gradation standards and specifications.
5. *Reservoir Layer.* The reservoir sub-base consists of 1.5 to 3 inches crushed stone. The depth of this layer depends on the desired storage volume, which is a function of the soil infiltration rate, void spaces, and, in colder climates, the depth of the frost line, but typically ranges from 2 to 4 feet. The reservoir layer should be designed to drain completely in 48 to 72 hours. Table 3 provides further details on standards and specifications.
6. *Bottom Filter Layer.* This layer serves to stabilize the reservoir layer and is the interface between the reservoir layer and the filter fabric covering the underlying soil. It consists of a 2 inch thick layer of 0.5 inch crushed stone. Table 3 provides further details on standards and specifications.
7. *Filter Fabric.* It is very important to line the entire trench area, including the sides, with filter fabric prior to placement of the aggregate. The filter fabric serves a very important function by inhibiting soil from migrating into the reservoir layer and reducing storage capacity. Table 3 provides further details on standards and specifications.
8. *Underlying Soil.* The underlying soil should have an infiltration capacity of at least 0.3 in/hr, but preferably greater than 0.50 in/hr. Soils at the lower end of this range may not be suited for a full infiltration system. Infiltration rates for several soil types are given in Table 3 (Yu and Kaighn, 1992).
9. *Construction Practices (adapted from Schueler, 1992).*
   (1) All adjacent areas should be stabilized to prevent any sediment from washing onto the pavement surface, leading to premature clogging.
   (2) The subgrade shall be prepared as required while limiting undue compaction; permeability must be maintained. Equipment with tracks or over-sized rubber tires shall be used; DO NOT use vehicles with standard rubber tires.
   (3) The reservoir base course shall be laid in lifts over the base filter course and lightly compacted. The base courses should be kept free of all dirt and debris during construction.
   (4) The asphalt layer shall be laid directly over the top filter course in one lift. The laying temperature should be between 240 and 260 EF. The ambient temperature should be above 50 EF.
   (5) Compaction should take place when the surface is cool enough to resist a 9-Mg roller (class equivalent of a 10-ton roller). One or two passes is all that is required for proper compaction. Any more may reduce porosity.
   (6) Transporting of the mix to the site shall be in clean vehicles with smooth

dump beds that have been sprayed with a non-petroleum release agent. The mix should be covered during transport to limit cooling.

(7) After final rolling, no vehicular traffic of any kind should be permitted on the pavement until cooling and hardening has taken place; no sooner than six hours but preferably a day or two.

Table 3. Standards and specifications for design of porous pavements.

Layer	*Thickness*	*Material*	*Specifications*	*Comments*
Pavement	51-102 mm	Open Graded Aggregate	ASTM D 693-77 *"Crushed Stone, Crushed Slag, and Crushed Gravel for Dry or Water-Bound Macadam Base and Surface Courses of Pavements"*	Two exceptions: 1) open graded. 2) soundness test required per ASTM D 692-79.
		Asphalt	Asphalt Grade: AASHTO M-20.	For 85 to 100 penetration road asphalt as a binder in the northern U. S., 65 to 80 in the middle States, and 50 to 65 in the southern States.
			Viscosity Grade: AC-20 AASHTO M-226-73 I.	Use as a starting point; may be altered as necessary.
			Stripping Resistance: ASTM D1664.	If estimated coating area is not above 95%, add anti-stripping agent to mix.
			Asphalt Content: 5.75-6 % of weight of dry aggregate; test using FHWA Report No. FHWA-RD-74-2.	
Gravel Filters/Reservoir	Top Filter: 25-51 mm	13-mm Dia. Aggregate	Local Highway Dept. Specifications for Crushed Stone.	All aggregates must be washed to remove fines to prevent clogging.
	Reservoir Layer: 0.61-1.21 m	25-76-mm Dia. Aggregate	Local Highway Dept. Specifications for Crushed Stone.	All aggregates must be washed to remove fines to prevent clogging.
	Bottom Filter: 51 mm	13-mm Dia. Aggregate	Local Highway Dept. Specifications for Crushed Stone.	All aggregates must be washed to remove fines to prevent clogging.
Filter Cloth	-	Filter Cloth	MIRIFI # 14 N or equivalent.	

Note: Adapted from Schueler, 1992.

Table 4. Soil types for porous pavement systems.

Soil Type	Minimum Infiltration Rate (mm/hr)	SCS Soil Group	Maximum Depth of Storage (m)[1]	
			48 hr Drain Time	72 hr Drain Time
Sand	210	A	25	15
Loamy Sand	61.2	A	7.4	4.4
Sandy Loam	25.9	B	3.1	4.6
Loam	13.2	B	1.6	2.4
Silt Loam	6.85	C	0.81	1.2

Note : 1. Maximum depth of storage that can be drained within the specified time.

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